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II. THE KELLAWAYS BEDS OF THE AREA BETWEEN CHIPPENHAM AND MALMESBURY, WILTSHIRE

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Text-figures 1-4

Summary. The Kellaways Beds of the type-area near Chippenham in Wiltshire are described. The Kellaways Clay is a variable sandy clay up to 21.5 m thick, overlying the Upper Cornbrash. The Kellaways Sand is a lenticular bed of sand up to 4.25 m thick separating the Kellaways Clay below from the Oxford Clay above. Within the area, a borehole has proved a full thickness of Kellaways Beds and all the Callovian ammonite zones up to the *Erymnoceras coronatum* Zone, *Kosmoceras obductum* Subzone.

INTRODUCTION

DURING THE recent primary 6-in survey of the 1-in Bath (265) and the 1-in Malmesbury (251) sheets, the ground north of Chippenham, Wiltshire, including part of the former parish of Kellaways, was mapped (Fig. 1). This includes the type-locality of the Kellaways Clay and overlying Kellaways Sand (or Rock), together comprising the Kellaways Beds, which are exposed in the banks of the River Avon south of Kellaways Bridge [9468 7578]¹. The area also covers the type-localities of the two Lower Callovian ammonite zones (*Macrocephalites macrocephalus* and *Sigaloceras calloviense*). In 1970-1, the Bristol Avon River Authority drilled two boreholes in the area: Tytherton No. 2 [9558 7282] and Tytherton No. 3 [9440 7445] (Fig. 2), the former proving a full thickness of Kellaways Beds. Detailed descriptions of these borehole sequences are given in the Appendix.

The 1-in geological maps of the Bath and Malmesbury districts have now been published. The forthcoming memoir on the Malmesbury district will include only a brief account of the Kellaways Beds, based on the few exposures, with some evidence from boreholes, within that 1-in Sheet. The areas to the east are included on the Swindon (252) Sheet and the Marlborough (266) Sheet; primary 6-in survey of the former area has been completed recently and the latter district is covered by a map and memoir (White 1925). This paper presents some new information about the Kellaways Beds in their type-area.

HISTORY OF RESEARCH

The Kellaways Clay and Kellaways Rock were first recognized by William Smith in the banks of the River Avon near Kellaways, Wiltshire. In 1813, Townsend wrote a book in which he used a stratigraphical succession established by Smith, and there the term 'Kelloway Rock' was published for the first time with a brief description. Following the publication of his map in 1815, Smith produced his own description of the strata with some illustrations of fossils from the 'Kelloways Stone' (1817).

¹ National Grid references are given in this form throughout the paper. All lie within the 100-km grid square ST, unless otherwise stated.

The first study of a more regional nature was that of Lonsdale (1829) who in describing the geology of the area around Bath included the 'Kelloway Rock' with lists of fossils from 'Kelloway' Bridge, Christian Malford and Whitley near Melksham, and recorded a section in a quarry at Christian Malford.

The construction of the Great Western Railway through the area in the mid-nineteenth century exposed new sections through the Kelloways Beds which, together with the fossils that they yielded, provided data for the papers by Pratt (1841), on the cuttings between Chippenham and Wootton Bassett, and G. A. Mantell (1848) and R. N. Mantell (1850) on the branch line from near Chippenham through Trowbridge to Westbury.

H. B. Woodward (1895), in his treatise on the Jurassic rocks of Britain, described most of the available sections in the area, particularly the numerous small brickyards in the Oxford Clay. In his generalized account of the Kelloways Beds of the area, he described 30 to 40 ft (9 to 12 m) of "Bands of loamy clay sand and calcareous and shelly sandstone, fossiliferous" overlying 12 to 20 ft (3.5 to 6 m) of "Clay, ochreous and sandy, and blue clay, with much selenite and an occasional band of septaria". Later (1899) he described sections seen in cuttings on the South Wales Direct Line near Brinkworth, Great Somerford and Bincombe Wood. Reynolds and Vaughan (1902) also described sections on this line between Filton and Wootton Bassett.

White (1925) described sections on the 1-in Marlborough (266) Sheet in the relevant memoir and included in his account, the type-locality of the Kelloways Beds. He gave extensive lists of fossils from Kelloways and district based on the collections of J. Rhodes and H. B. Woodward and revised by S. S. Buckman and J. Pringle.

Callomon (1955, 1964) provided detailed information on the ammonite sequences of these Beds and established a zonal scheme based on this. The Kelloways Beds of Chippenham, Wiltshire are the stratotype of the *Sigaloceras calloviense* Zone and the Chippenham-Trowbridge area of Wiltshire is the type-locality for the underlying *Macrocephalites macrocephalus* Zone. Most recently, Barron (1972) has recorded sections seen during the construction of the M4 motorway through Wiltshire which passed north of Christian Malford and Sutton Benger.

Some of the localities mentioned above are described more fully in the text. These are shown as numbered localities in Fig. 2.

GENERAL STRATIGRAPHY

The Kelloways Clay, Kelloways Sand and Oxford Clay, differentiated by their distinctive lithologies, have been mapped within the area, often with the use of an auger. The main outcrop ranges between Chippenham and Malmesbury, extending westwards to Norton and Foxley and northwards as far as Brokenborough. A few small outliers of Kelloways Clay also occur to the north-west around Tetbury (Fig. 1).

KELLOWAYS CLAY

The Kelloways Clay is characteristically a silty grey clay, weathering brown or orange-brown, with impersistent thin layers and lenticular beds of sand. By piecing together available information from the literature and museum collections, Callomon (1955) established a faunal and lithological sequence for the Kelloways Clay between Chippenham and the Mendips, showing a phosphatic facies below and a pyritic facies above each characterized by a distinctive

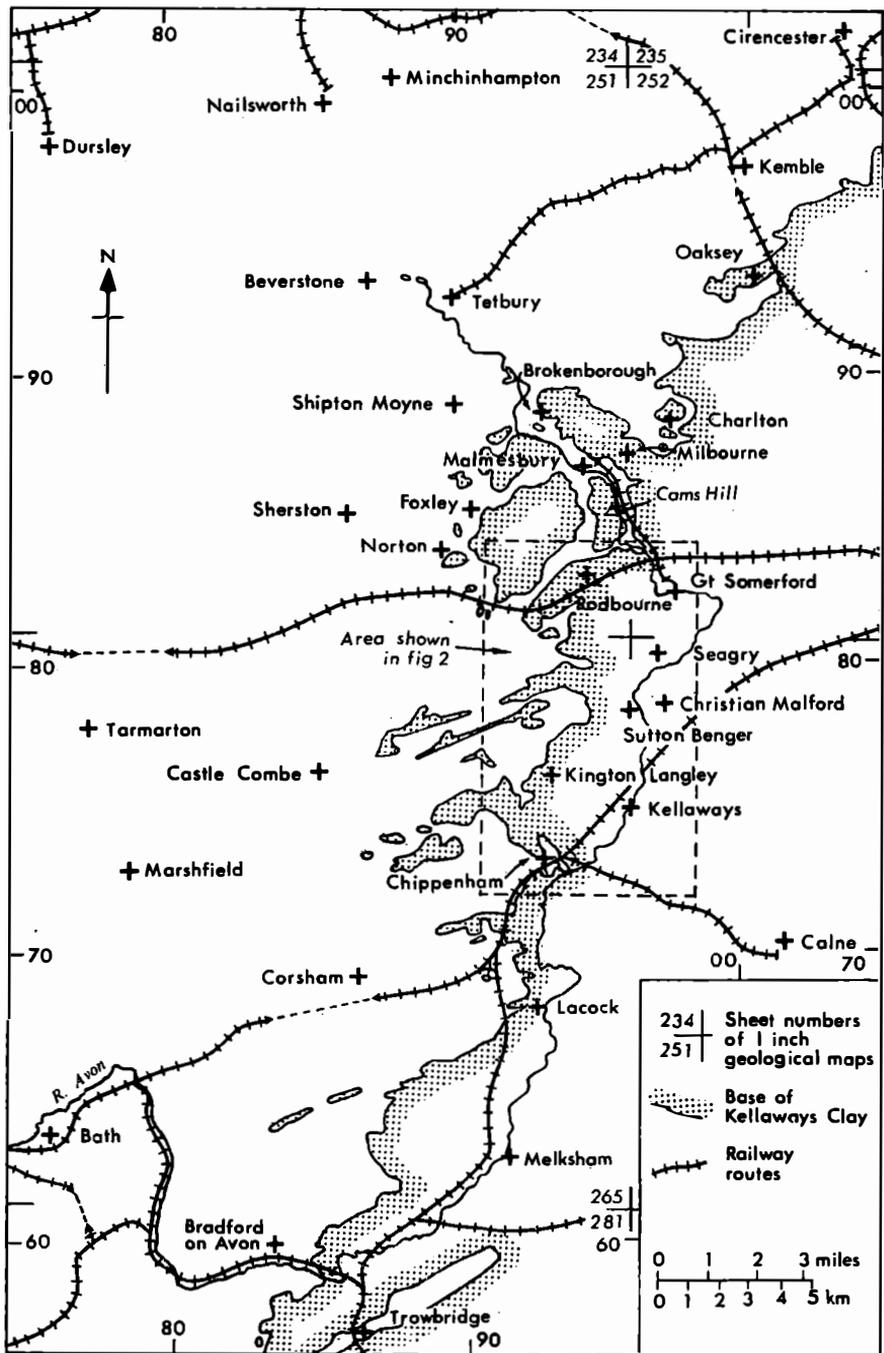


FIG. 1. Location map showing the outcrop of the base of the Kellaways Clay

faunal preservation. In the Tytherton No. 2 Borehole (see Appendix), the Kellaways Clay is rich in pyrite (as trails, knots and bivalve relics) down to a depth of about 39·30 m with uncrushed inner whorls of ammonites preserved in pyrite (e.g. *Proplanulites* at 33·08 m). Below this, a phosphatic nodule is recorded at 41·54 m with a similarly infilled *Modiolus* at 42·20 m; ammonites are rare at this level, so further evidence of Callomon's phosphatic facies is wanting. In the Tytherton No. 3 Borehole, pyrite knots, trails, patches, staining and shell infillings occur scattered throughout the Kellaways Clay.

KELLAWAYS SAND

The outcrop of the Kellaways Sand has been mapped from just south of Chippenham northwards to Cam's Hill (Fig. 2). It is characteristically a rather coarse gritty silica sand, but in boreholes and deep excavations it is a pale grey, hard, calcareous sandstone or a sandy fossiliferous limestone. For these latter conditions, the term Kellaways Rock is used. Historically, the term Kellaways Rock has priority since Townsend (1813) first used the term for the beds cropping out in the banks of the River Avon. It seems useful, however, to continue the use of the two terms, Sand and Rock, as local conditions demand. The extent to which the sand seen at outcrop is the result of decalcification of sandy limestone is not known.

The lithological change from the Kellaways Clay is everywhere transitional, with muddy sandstones and siltstones interbedded with more pure sandstones and mudstones; the boundary between the two is therefore to some extent arbitrary. In this paper, all these transitional beds are placed with the Kellaways Clay. South of Chippenham and probably north-east of Malmesbury, the Oxford Clay locally rests on Kellaways Clay. The Kellaways Sand thus appears to be a local and variable development at the top of the Kellaways Clay.

The thickness of the Kellaways Clay with the Kellaways Sand/Rock, where present, seems to be fairly constant throughout the area. D. R. A. Ponsford estimated the thickness of the Kellaways Clay to be about 23 m W of Melksham and some 24 m near Lacock (Fig. 1). Farther north, near Chippenham, the thickness is estimated to be about 24 m and a borehole at Sutton Benger [9443 7874] proved a thickness of 25 m of beds including about 4 m of Kellaways Sand. Evidence from a borehole on top of Cam's Hill [9396 8583] gives an estimated total thickness for the Kellaways Sand and Clay of 24 m and at Milbourne [9487 8763] 24 m of these beds, including 2·5 m of Kellaways Sand, were proved. At Sandpool Farm near Oaksey [SU 0122 9427], a borehole proved 28·6 m of Kellaways Clay with no record of Kellaways Sand. North-eastwards from here, the Kellaways Rock is again present as recorded in the railway cutting at South Cerney near Cirencester, Gloucestershire [SU 045 980], where Harker (1886) described a sequence of ferruginous and calcareous sands and sandstones, up to 19 ft 6 in (5·9 m) thick, overlying the Kellaways Clay.

The Tytherton No. 3 Borehole, near the type-locality, started in Kellaways Rock of which it proved 3·6 m overlying 17·3 m of Kellaways Clay. The Tytherton No. 2 Borehole proved a total thickness for the Kellaways Beds of 18·6 m. Here the boundary between the Kellaways Rock and Clay was rather difficult to draw. The transitional beds are some 8 m thick and rather sandy in character; the lower boundary of the Kellaways Rock has been taken at 28·75 m, at the highest interburrowed junction between shelly sandstone on muddy siltstone. This gives a range in thickness, in this area, of 2·5 to 4·25 m for the Kellaways Rock/Sand and 15·8 to 21·5 m for the Kellaways Clay.

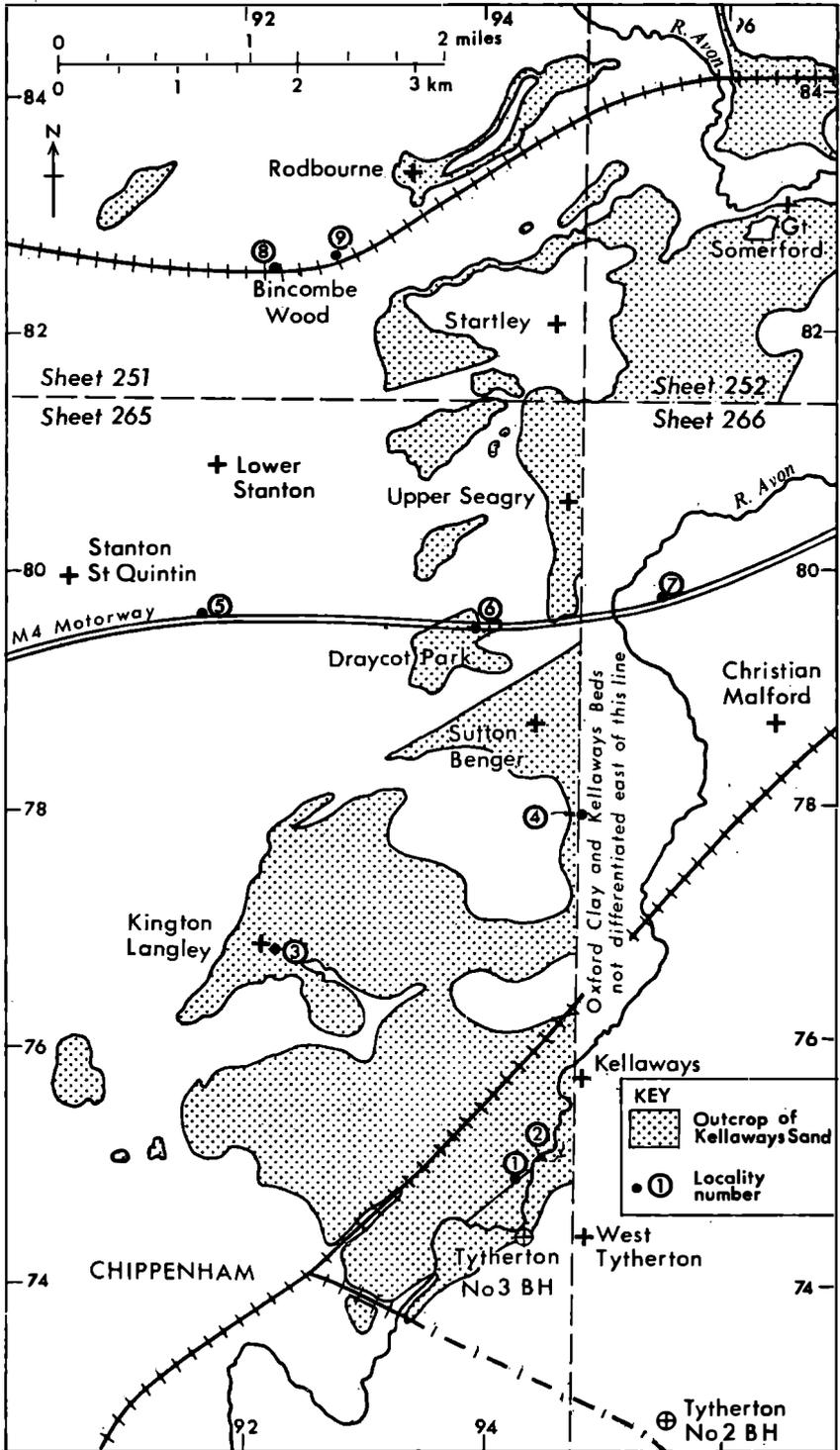


FIG. 2. Locality map showing the outcrop of the Kellaways Sand

DETAILS

At Locality 1 (Fig. 2) [9432 7489] 668 m N80°E of Lower Peckinggell Farm, a dug river channel exposed: soil etc., 0·9 m; on Kellaways Sand consisting of sand, pale grey and yellow with hard nodules, 0·9 m; sand, dark grey and firm with rusty fossiliferous patches, seen 0·9 m. 110 m to the north-east [9425 7495] at the confluence with the main river, the following similar beds were seen: soil, 0·3 m; on Kellaways Sand consisting of sand, yellow-brown, clean, 0·6 m; sandstone, yellow-brown, clean, 0·15 m; clay, sandy and very shelly, 0·3 m; clay, sandy, mottled, grey-brown, 0·45 m; sand, grey with fossil wood, seen 1·2 m. The fauna from these exposures includes:

Ornithella ornithocephala auctt.
Catinula alimena (d'Orbigny)
Modiolus bipartitus J. Sowerby

Pleuromya sp.
 belemnite fragments

A similar section was described by Woodward (1895, p. 29). Fossils from exposures in the banks of the River Avon were listed, with other localities on the Marlborough (266) Sheet, in the memoir of that sheet (White 1925). White referred to two exposures (1925, pp. 11–2) which are taken to be the type-localities (Locality 2, Fig. 2), as follows:

A. "River Avon, near footbridge $\frac{1}{2}$ mile (805 m) S of Kellaways Church"—described as "Kellaways Rock". The faunal list has been revised as follows:

Pentacrinus columnals
Ornithella ornithocephala
Rhynchonelloidella cf. *socialis*
 (Phillips)
Chemnitzia sp.
Dicroloma sp.
Pictavia aff. *punctura* (Bean)
Procerithium sp.
Turbo ?
Dentalium sp.
Anisocardia sp.
Astarte sp.
Barbatia sp.
Camptonectes sp.
Catinula alimena
Chlamys (*Aequipecten*) *fibrosa*
 (J. Sowerby)
Corbula ?
Cucullaea ?
Gervillella sp.
Goniomya sp.

Grammatodon sp.
Gryphaea spp.
Isocyprina sp.
Modiolus sp.
Oxytoma inaequalvis (J. Sowerby)
Pinna sp.
Placunopsis aff. *semistriata* (Bean)
Pleuromya alduini (Brongniart)
P. calceiformis (Phillips)
Protocardia sp.
Tancredia ?
Cadoceras sp.
Parapatoceras calloviense (Morris)
Proplanulites sp.
Pseudocadoceras cf. *schmidti*
 (Pompeckj)
Sigaloceras (*S.*) *calloviense*
 (J. Sowerby)
 belemnite fragments
 wood fragments

B. "Side of stream, River Avon, over $\frac{1}{2}$ mile (805 m) S of Kellaways Church"—described as "Kellaways Beds. Blue sandy clay with septaria below Kellaways Rock". The faunal list has been revised as follows:

Chemnitzia sp.
Dicroloma sp.
Pictavia ?
Anisocardia sp.
Barbatia sp.
Catinula sp.
Chlamys (*A.*) *fibrosa*

Entolium (*E.*) cf. *demissum* (Phillips)
Grammatodon sp.
Gryphaea sp.
Modiolus bipartitus
Myopholas acuticostata
 (J. de C. Sowerby)
Oxytoma expansa (Phillips)

Pinna sp.
Pleuromya alduini
P. aff. uniformis (J. Sowerby)
Protocardia sp.
Quenstedtia?
Cadoceras sp.
Parapatoceras calloviense

Proplanulites sp.
Sigaloceras (S.) aff. *calloviense*
S. (Gulielmina) aff. *quinqueplicatum*
 (S. S. Buckman)
 belemnite fragments
 wood fragments

Other specimens in the Institute collections from Kellaways, Wiltshire include:

Rugitela?
Gryphaea (Bilobissa) cf.
sublobata Deshayes
Isognomon sp.
Myophorella sp.
Pholadomya sp.
Pseudolimea duplicata
 (J. de C. Sowerby)
Cadoceras cf. *durum*
 (S. S. Buckman)
C. aff. milashevici (Nikitin)
C. cf. sublaeve (J. Sowerby)
Grossouvria sp.
Keplerites (K.) crucifer
 (S. S. Buckman) (HOLOTYPE)
K. (K.) curtilobus (S. S. Buckman)
 (HOLOTYPE)

oppeliids?
Proplanulites capularis S. S. Buckman
P. excentricus S. S. Buckman
P. fulvus S. S. Buckman (HOLOTYPE)
P. lentus S. S. Buckman (HOLOTYPE)
P. lyprus S. S. Buckman (HOLOTYPE)
P. oidaleus S. S. Buckman (HOLOTYPE)
P. opimus S. S. Buckman
P. partitus S. S. Buckman (HOLOTYPE)
P. petrosus S. S. Buckman (HOLOTYPE)
P. rudis S. S. Buckman
P. stiphrus S. S. Buckman (HOLOTYPE)
P. tridens S. S. Buckman (HOLOTYPE)
Sigaloceras (G.) quinqueplicatum

At Kington Langley (Locality 3, Fig. 2) temporary exposures in drainage trenches on Kington Langley Common were examined by K. J. Ackermann in 1965.

A. [923 768] 1463 m S25°W of Upper Draycott and 122 m E5°N of Fitzhurse Moat

B. [9225 7686] 122 m N84°E of Fitzhurse Farm

Fossils were collected from two horizons: (A) calcareous nodules, probably 0.45 to 0.6 m below the Kellaways Sand (*ex situ*), (B) limestone nodules in the Kellaways Sand.

Horizon A yielded:

Ornithella ornithocephala
Rhynchonelloidella cf. *socialis*
Chemnitzia sp.
Dicroloma sp.
Pleurotomaria?
Procerithium sp.
Anisocardia sp.
Camptonectes?
Catinula aff. *alimena*
Chlamys (A.) fibrosa
Entolium (E.) demissum
Goniomya literata (J. Sowerby)
Grammatodon sp.
Isocyprina sp.
Modiolus bipartitus
Myophorella sp.

Oxytoma cf. *expansa*
O. inaequivalvis
Pholadomya aff. *deltoidea*
 (J. Sowerby)
Pleuromya alduini
Protocardia sp.
Pseudolimea?
Trigonia sp.
Cadoceras cf. *sublaeve*
C. aff. sublaeve var. *communis* Spath
Keplerites (K.) aff. *curtilobus*
K. (K.) cf. *kepleri* (Oppel)
Proplanulites spp.
Sigaloceras sp.
 belemnite fragments
 wood fragments

Horizon B yielded:

<i>Pentacrinus columnals</i>	<i>Myopholas</i> cf. <i>acuticostata</i>
<i>Ornithella ornithocephala</i>	<i>Myophorella</i> sp.
rhynchonellid	<i>Oxytoma expansa</i>
<i>Chemnitzia</i> sp.	<i>Pinna</i> sp.
<i>Dicroloma</i> sp.	<i>Pleuromya alduini</i>
<i>Pictavia</i> aff. <i>punctura</i>	<i>Protocardia</i> sp.
<i>Procerithium</i> sp.	<i>Pseudolinea</i> aff. <i>duplicata</i>
<i>Dentalium</i> sp.	<i>Cadoceras</i> aff. <i>sublaeve</i>
<i>Anisocardia</i> sp.	<i>Keplerites</i> (<i>K.</i>) aff. <i>trichophorum</i>
<i>Astarte</i> sp.	(S. S. Buckman)
<i>Chlamys</i> (<i>A.</i>) <i>fibrosa</i>	<i>Parapatoceras calloviense</i>
<i>Entolium</i> (<i>E.</i>) <i>demissum</i>	<i>Proplanulites</i> sp.
<i>Gervillia</i> sp.	<i>Pseudocadoceras</i> sp.
<i>Grammatodon</i> sp.	<i>Sigaloceras</i> (<i>G.</i>) <i>quinqueplicatum</i>
<i>Isocyprina</i> sp.	wood fragments

Debris from the Kellaways Sand was seen after the construction of foundations for electricity pylons just south of Sutton Benger. One of these (Locality 4, Fig. 2) [9505 7795] 841 m SSE of Sutton Benger Church, yielded debris consisting of rather pale grey, calcareous sandstone containing abundant oolites of calcium carbonate. Similar debris and fossils were seen 384 m to the SSW [951 776] and the fauna from both includes:

<i>Ornithella ornithocephala</i>	<i>Modiolus bipartitus</i>
<i>Rhynchonelloidella socialis</i>	<i>Myophorella</i> sp.
<i>Anisocardia</i> sp.	<i>Oxytoma</i> sp.
<i>Barbatia</i> ?	<i>Pleuromya alduini</i>
<i>Catinula alimena</i>	<i>Proplanulites</i> sp.
<i>Codakia</i> (<i>Epilucina</i>) sp.	<i>P.</i> (<i>Crassiplanulites</i>) sp.
<i>Goniomya</i> sp.	<i>Sigaloceras</i> (<i>S.</i>) <i>calloviense</i>
<i>Gryphaea</i> (<i>B.</i>) <i>sublobata</i>	

Localities 5, 6 and 7 (Fig. 2) are temporary sections made during the construction of the M4 motorway in 1969 and 1970. A considerable part of the fossil collecting was done by Mr J. H. Tucker who recorded some of the sections (Barron 1972).

Locality 5: [9170 7960] near Stanton St Quintin. Drift about 1.2 m; on Kellaways Clay consisting of clay, grey, 1.8 m; harder, silty, calcareous bed, about 1.2 m; over Cornbrash limestone. The silty, calcareous bed yielded the following fauna:

<i>Ornithella ornithocephala</i>	<i>Myophorella</i> sp.
<i>Anisocardia</i> sp.	<i>Pholadomya</i> sp.
<i>Barbatia</i> sp.	<i>Pleuromya</i> cf. <i>alduini</i>
<i>Goniomya</i> sp.	<i>P. uniformis</i>
<i>Modiolus</i> cf. <i>bipartitus</i>	

Locality 6: [940 795], Draycot Park, was an exposure of Kellaways Clay on the levelled embankments of the motorway cutting. It showed grey clays with scattered pale grey, calcareous nodules. The upper part of the embankment became sandy westwards revealing overlying Kellaways Sand. The following fossils were collected *ex situ*:

<i>Gryphaea</i> (<i>Bilobissa</i>) aff.	<i>Cadoceras sublaeve</i>
<i>bilobata</i> (J. Sowerby)	<i>Chamousetia lenticularis</i> (Phillips)
<i>G.</i> (<i>B.</i>) <i>sublobata</i>	<i>Choffatia</i> sp.
<i>Trigonia</i> sp.	<i>Keplerites</i> (<i>K.</i>) <i>galilaei</i> (Oppel)

<i>K. (Gowericeras) gowerianus</i> (J. de C. Sowerby)	<i>P. cf. koenigi</i> (J. Sowerby)
<i>Proplanulites (Crassiplanulites)</i> cf. <i>crassicosta</i> (S. S. Buckman)	<i>Paracnoceras aff. herznachensis</i> Jeannet

The following fauna, occurring in a harder matrix, was collected near the above locality:

<i>Barbatia aff. prattii</i> (Morris & Lycett)	<i>Myophorella sp.</i>
<i>Modiolus bipartitus</i>	<i>Pleuromya alduini</i>

The following were also recorded:

<i>Grammatodon sp.</i>	<i>Protocardia sp.</i>
<i>Pleuromya uniformis</i>	

Locality 7: [956 798] is a section north of Christian Malford in grey clays (Kellaways Clay), below sandy material, in places reddish, calcareous, ferruginous, fossiliferous sandstone (Kellaways Sand). Fossils collected *ex situ* include:

<i>Ornithella ornithocephala</i>	<i>Cadoceras sp.</i>
<i>Catinula sp.</i>	<i>Keplerites (K.) curtilobus</i>
<i>Pleuromya alduini</i>	<i>K. (Gowericeras) cf. toricellii</i> (Oppel)

To the east of the above locality, the following section was recorded by Mr J. H. Tucker [959 799]:

Soil	ft	in	(m)
	.. up to 2	0	(0.61)

KELLAWAYS SAND

Sandstone, dark, red-brown, ferruginous with <i>Ornithella ornithocephala</i> , <i>Rhynchonelloidella sp.</i> , <i>Catinula cf. alimena</i> , <i>Gryphaea (B.) aff. sublobata</i> , <i>Pleuromya alduini</i> and <i>Sigaloceras (S.) calloviense</i> ..	4	0	(1.22)
Sand	0	6	(0.15)
Limestone, sandy ferruginous with <i>O. ornithocephala</i> and <i>Anisocardia sp.</i>	6	6	(1.98)
Brachiopod 'bed' with <i>O. ornithocephala</i>	0	5	(0.13)
Limestone, ferruginous, sandy with brown concretions	2	6	(0.76)

KELLAWAYS CLAY

Clay, blue-grey	seen 2	0	(0.61)
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Also collected from this exposure were:

Cadoceras sp. (juv.), *Keplerites (K.) curtilobus*, *Sigaloceras (G.) quinqueplicatum*.

This section appears to be very near that described by Barron (1972, p. 4), where 0.6 m of clay, presumably Oxford Clay, was seen above the Kellaways Sand and more than 10.0 m of Kellaways Clay seen below it.

The basal beds of the Kellaways Clay were visible in the stream bank [9447 7966], 1143 m SSW of Upper Seagry crossroads, as follows: 2.44 m of grey and orange-brown sand, on 0.61 m of light grey-brown silty sand, and 0.3 m of clay resting on Cornbrash limestone.

Localities 8 and 9 of Fig. 2 are sections on the South Wales Direct Line described by Woodward (1899) and Reynolds and Vaughan (1902). These are included in the memoir of the Malmesbury Sheet (Cave, in press).

In Fig. 3, the sequence in the Tytherton No. 2 Borehole is shown graphically, together with some of the ammonite occurrences and the sequence of ammonite zones and subzones that have been recognized; the sections at the various localities, described above, are shown in relation to this borehole sequence.

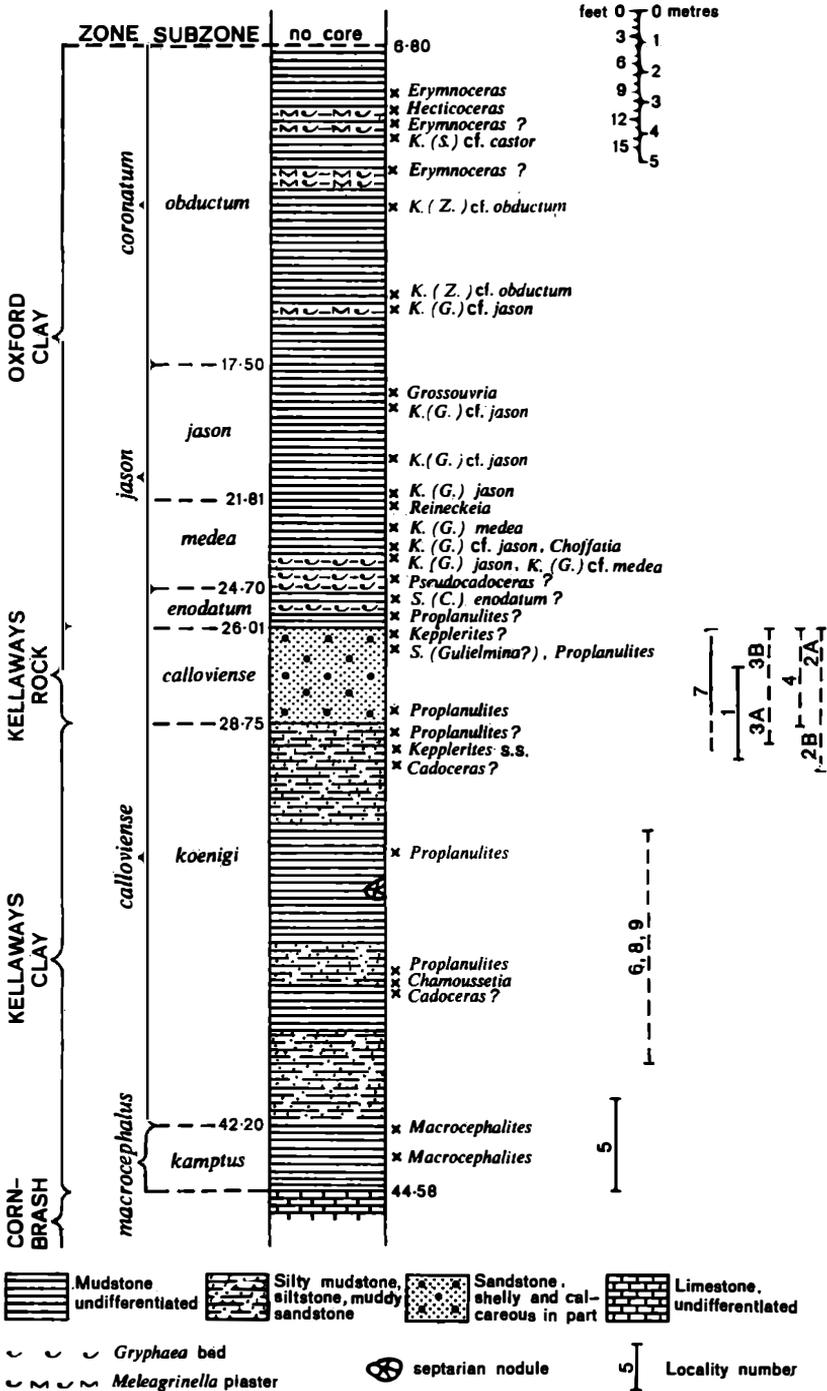


FIG. 3. The sequence in the Tytherton No. 2 Borehole showing the ammonite zones, with some selected ammonite occurrences, and the relationship with the sections at Localities 1 to 9

ZONAL STRATIGRAPHY

Oppel (1857, pp. 503–18) divided his Kellowaygruppe (Callovien) of Wiltshire into three ammonite zones. The upper two—zones of *Ammonites athleta* and *Amm. anceps*—are represented by part of the Oxford Clay. His lowest zone (*Amm. macrocephalus*) included in its upper part, a zone of *Amm. calloviensis* represented by the “Kelloway-Stone von Kelloway-Mill” [Kellaways Rock] and characterized by “*Ammonites Calloviensis, Kōnighi, modiolaris, Gowerianus*” (Oppel 1857, pp. 506, 515). The lower part was represented by “Clay with nodules von Trowbridge” [Kellaways Clay]. Woodward (1895, p. 8) extended the *calloviensis* Zone downwards to include the Kellaways Clay, thereby restricting the *macrocephalus* Zone to the Cornbrash (Woodward 1894, p. 434). These two zones have formed the basis of the current zonal scheme for the Lower Callovian. Callomon (1955) formally divided them into five subzones to cover the Upper Cornbrash, Kellaways Clay and Kellaways Rock, as shown in Fig. 4. The boundary between the Upper Cornbrash and the Kellaways Clay is diachronous, lying between the top of the *Macrocephalites macrocephalus* Subzone and the base of the *Proplanulites koenigi* Subzone. In Wiltshire, the *Macrocephalites kamptus* Subzone may be represented by Upper Cornbrash and/or Kellaways Clay. This zonal scheme is discussed fully by Callomon (1955, 1964).

Macrocephalites macrocephalus* Zone**M. kamptus* Subzone**

The type-locality of this subzone is Kidlington, Oxfordshire. In southern and central England, it is typically developed in black shaly clay (lower Kellaways Clay), with pyrites and buff phosphatic nodules (Callomon 1968, p. 270). Callomon has traced it from Yeovil, Somerset to Peterborough, Northamptonshire, with a thickness range of 3½ to 25 ft (1·1–7·6 m). Its characteristic ammonites are *Macrocephalites (Kamptocephalites)* and *M. (Dolikephalites)*. Elsewhere, it may be present entirely, or in part, as Cornbrash. In our area, it is represented by the lower (phosphatic) part of the Kellaways Clay, characterized by ammonites in which inner whorls are usually missing and body chambers preserved in buff marl, covered by a chocolate-coloured layer (Callomon 1955, p. 247). In the Tytherton No. 2 Borehole, it is taken as the lowest 2·38 m of Kellaways Clay and by analogy, the lowest 1·87 m of Kellaways Clay in Tytherton No. 3 (see Appendix). Small fragments of specifically indeterminate *Macrocephalites* were recorded in the former borehole in a medium grey mudstone lithology, silty and sandy in part, with *Corbulomima*, *Modiolus*, small oysters, *Procerithium* and serpulids.

Sigaloceras calloviense* Zone**Proplanulites koenigi* Subzone**

Callomon (1955, p. 258) was the first to formally restrict Buckman's Zone of *Proplanulites koenigi* (1913, p. 154) to beds equivalent in age to the upper (pyritic) part of the Kellaways Clay of Wiltshire. (Buckman used the zone for the fossiliferous (i.e. lower) part of the Kellaways Rock of Scarborough (i.e. excluding the Hackness Rock)). Later, Callomon (1964, p. 276) wrote “it seems useful to retain it [*koenigi*] to indicate one of the two successive faunas that can be distinguished there [Wiltshire]”. Thus, in our area, the subzone is represented by the upper part of the Kellaways Clay characterized by ammonites (*Cadoceras*, *Chamoussetia*, *Choffatia*, *Grossouvria*, *Keplerites*, *Macrocephalites* (*Indo-*

OPPEL (1857)		FORMATION	CURRENT CLASSIFICATION			
STAGE	ZONE		SUBZONE	ZONE	STAGE	
Oxfordgruppe (pars)	<i>Amm. biarmatus</i> (pars)	Oxford Clay	<i>Cardioceras</i> <i>praecordatum</i>	<i>Quenstedtoceras</i> <i>mariae</i>	Oxfordian (pars)	
			<i>Cardioceras</i> <i>scarburgense</i>			
Kellowaygruppe	<i>Amm. athleta</i>				<i>Quenstedtoceras</i> <i>lamberti</i>	Callovian
					<i>Peltoceras</i> <i>athleta</i>	
	<i>Amm. anceps</i>			<i>Kosmoceras</i> <i>grossouvrei</i>	<i>Erymnoceras</i> <i>coronatum</i>	
				<i>Kosmoceras</i> <i>obductum</i>		
				<i>Kosmoceras jason</i>	<i>Kosmoceras</i> <i>jason</i>	
				<i>Kosmoceras medea</i>		
				<i>Amm. calloviensis</i>	Kellaways Rock/Sand	
	<i>Sigaloceras</i> <i>calloviense</i>					
<i>Proplanulites</i> <i>koenigi</i>						
<i>Amm. macrocephalus</i>	Kellaways Clay	<i>Macrocephalites</i> <i>kamptus</i>	<i>Macrocephalites</i> <i>macrocephalus</i>			
	Upper Cornbrash	<i>Macrocephalites</i> <i>macrocephalus</i>				
Bathgruppe (pars)	<i>Terebr. lagenalis</i> (pars)	Lower Cornbrash	<i>Clydoniceras</i> <i>discus</i>	<i>Clydoniceras</i> <i>discus</i> (pars)	Bathonian (pars)	

FIG. 4. Table showing the ammonite zonation of the Kellaways Beds of Wiltshire

cephalites), *M. (Pleurocephalites)*, *Proplanulites*) having complete inner whorls preserved in pyrite with a white covering, and with characteristic white chalky body chambers (Callomon 1955, p. 247).

The subzone is distinguished from the *kamptus* Subzone below by the strong incoming of boreal ammonite genera such as *Cadoceras*, *Chamoussetia* and *Keplerites*, together with *Proplanulites*. From Wiltshire southwards, it is represented by the upper part of the Kellaways Clay (Callomon 1968, p. 270). In the Tytherton No. 2 Borehole, it is represented by 13.45 m of silty mudstones, siltstones, mudstones and some sandstones with *Cadoceras*, *Chamoussetia*, *Keplerites* s.s. and *Proplanulites*. In Tytherton No. 3, it is 15.45 m thick.

S. calloviense Subzone

Oppel (1857, p. 506) created the *calloviense* Zone for the Kellaways Rock of Wiltshire. Since then the zone has been extended to include part of the Kellaways Clay, with the fauna of the Kellaways Rock defining a *calloviense* Subzone within it.

In England, this subzone has been traced from Dorset to Peterborough, its base being marked by the incoming of *Sigaloceras*. As mentioned earlier, the passage between the Kellaways Rock and Kellaways Clay in our area is transitional, and the transitional beds have been assigned to the Kellaways Clay. The available ammonite evidence from these beds does not clearly indicate an association with the *calloviense* Subzone which, for convenience, remains restricted to the Kellaways Rock/Sand. However, amongst the specimens collected from the banks of the River Avon (Locality 2B, see p. 46) by J. Rhodes in 1887 are several specimens of *Sigaloceras*, some of which show characteristics transitional to *Keplerites*. The stratigraphical details given for these specimens suggest that they come from the transitional beds and the possibility that the *calloviense* Subzone includes part of these beds cannot be overruled. In the Tytherton No. 2 and No. 3 boreholes, the subzone was 2.74 m and 3.60 m thick respectively. *Sigaloceras (Gulielmina)*, *Proplanulites* and *Keplerites* were recorded.

S. enodatum Subzone

In England, this subzone has been recorded at Peterborough, Bedford, Bletchley and Kidlington, Oxfordshire, ranging in thickness from 8 in to 6 ft (0.2–1.8 m) (Callomon 1968, p. 271). Apart from at its type-locality (South Cave, Yorkshire), where it is developed in Kellaways Rock, the subzone is present in Oxford Clay facies. In the Tytherton No. 2 Borehole, it was present as 1.31 m of pale to medium grey mudstones with *Sigaloceras (Catasigaloceras) enodatum* (Nikitin) and *Kosmoceras (Gulielmiceras)* sp.

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APPENDIX

For the purposes of the present work, only detailed descriptions of the beds down to the top of the Cornbrash (44·58 m in Tytherton No. 2; 24·27 m in Tytherton No. 3) are given. A provisional classification for the Middle Jurassic beds to the base of the boreholes is included. In both boreholes, the core diameter is 70 mm.

Tytherton No. 2 Borehole

Drilled by Bristol Avon River Authority; December 1970 to January 1971.
National Grid reference ST 9558 7282. AOD 55 m estimated. IGS Specimen Nos. BDC 1641-2438.

This borehole was drilled to a depth of 102·75 m and proved a full Jurassic sequence from the Oxford Clay to the Fuller's Earth.

Description of Strata	Thickness m	Depth m
JURASSIC		
Core commences		6·80
OXFORD CLAY		
<i>Erymnoceras coronatum</i> Zone		
<i>Kosmoceras obductum</i> Subzone		
Mudstone, brownish grey to olive, with much shell debris; well laminated though crumbly in places; small bivalves and fragments including nuculoids and <i>Posidonia</i> ?; small gastropods	0·60	7·40
Mudstone, similar colour to above, fissile, shells better preserved than above with small gastropods and bivalves including <i>Oxytoma expansa</i> ; thin shattered band at base..	0·10	7·50
Mudstone, olive-grey, smooth-textured, with abundant small gastropods at 7·75 m; thick-shelled small bivalves, including <i>Palaeonucula</i> ?; <i>Posidonia</i> ; fragment of <i>Kosmoceras</i> at 8·20 m; becoming relatively unfossiliferous with depth; shattered band at 8·00 m	0·79	8·29
Mudstone, olive-grey, fissile along bedding with abundant shell debris and nacreous ammonite and bivalve fragments including <i>Oxytoma</i> and <i>Palaeoneilo</i> ; crushed fragment of <i>Erymnoceras</i> at 8·35 m	0·11	8·40
Mudstone, olive-grey, crumbly in texture with much shell debris which decreases in abundance with depth; wood fragments at 8·60 m with <i>Kosmoceras</i> (<i>Zugokosmoceras</i>) <i>sp.</i> ; becoming well laminated below with nacreous shell fragments and some complete small bivalves including nuculoids; <i>Thracia</i> , oyster fragments and <i>Procerithium</i> ; <i>Kosmoceras</i> fragments and <i>Hecticoceras sp.</i> at 8·83 m ..	0·50	8·90
Shell bed with abundant <i>Meleagrinnella</i> in plasters, and gastropods	0·10	9·00
Mudstone, olive-grey, with shell material becoming sparse downwards; <i>Meleagrinnella</i> not uncommon with thick-shelled nuculoids; <i>Dicroloma</i> ; <i>Kosmoceras</i> fragments and <i>Erymnoceras?</i> fragment at 9·12 m; becoming well laminated and fissile towards base	0·30	9·30

Description of Strata	Thickness m	Depth m
Shell bed with abundant <i>Meleagrinnella</i> in plasters; rather crumbly in texture	0.05	9.35
Mudstone, olive-grey, shell material decreasing downwards; <i>Kosmoceras</i> fragments with <i>K. (Spinikosmoceras) cf. castor</i> (Reinecke) at 9.40 m; <i>Meleagrinnella</i> common in plasters at 9.38 and 9.50 m, <i>Thracia</i> , thick-shelled nuculoids, <i>Dicroloma</i>	0.15	9.50
Mudstone, olive-grey, texture more crumbly downwards with increasing shell material to become very shelly with plasters of <i>Meleagrinnella</i> and rarer thick-shelled nuculoids at base	0.20	9.70
Mudstone, olive-grey, well laminated, fissile along bedding; shell debris, with some <i>Meleagrinnella</i> , becoming rarer downwards	0.20	9.90
Mudstone, olive-grey, shells more common with large pyritic <i>Meleagrinnella</i> and plaster of <i>Posidonia</i> ; <i>Kosmoceras</i> fragments, <i>Dicroloma</i> , <i>Procerithium</i> ; core disturbed	0.20	10.10
Core lost	0.20	10.30
Mudstone, olive-grey, with shell debris; <i>Meleagrinnella</i> , <i>Thracia</i> ; small <i>Procerithium</i> ? quite common; <i>Kosmoceras</i> fragments; core disturbed to 10.40 m	0.20	10.50
Mudstone, as above but less fossiliferous to 10.60 m; <i>Meleagrinnella</i> occurring down to 10.63 m with small indeterminate bivalves and fragments including oysters; small gastropods and crushed <i>Erymnoceras</i> ? fragment at 10.52 m; little shell debris and core well laminated ..	0.18	10.68
Mudstone, olive-grey, crumbly texture due to abundant shell debris, including plasters of large <i>Meleagrinnella</i> with oysters and gastropods	0.07	10.75
Mudstone, pale olive-grey, more calcareous and harder than above, with fracture rather blocky; <i>Palaeoneilo</i> and other bivalve fragments including oysters, indeterminate ammonite and gastropod fragments	0.15	10.90
Mudstone, olive-grey, shells more abundant and in places causing crumbly texture; <i>Meleagrinnella</i> common, forming plaster at 11.15 m, <i>Anisocardia</i> ?, <i>Palaeoneilo</i> and other thick-shelled nuculoids, oysters and other bivalve fragments; gastropods very common in places including <i>Procerithium</i> ; <i>Lingula</i> at 11.55 m; <i>Kosmoceras (Zugokosmoceras) cf. obductum</i> (Buckman) at 11.75 m and indeterminate <i>Kosmoceras</i> fragments; shell debris and fine pyritic debris in places	0.90	11.80
Mudstone, pale to medium greenish grey, rather more calcareous and silty and hence harder than above; small shell fragments scattered throughout; bivalves including <i>Palaeoneilo</i> and oysters; gastropods and a perisphinctid ammonite body chamber fragment at 11.82 m; small pyrite and tiny shell fragments scattered throughout; passing down into	0.50	12.30
Mudstone, greenish grey, quite hard; more uniformly textured than above; shell debris rare, small ' <i>Lucina</i> '? at 12.40 m ..	0.10	12.40

Description of Strata	Thickness m	Depth m
Mudstone, greyish green with blocky fracture; more shelly than above with bivalves including <i>Modiolus</i> ; <i>Procerithium</i> and rhynchonellid brachiopods at 12.63 and 12.65 m ..	0.30	12.70
Mudstone, silty, greyish green, relatively unfossiliferous with scattered small shell fragments; well laminated mudstone, breaking more evenly from 13.00 to 13.30 m; small oysters	0.80	13.50
Mudstone, pale grey, softer than above, well laminated; shells including <i>Chlamys fibrosus</i> , <i>Modiolus</i> , <i>Palaeoneilo</i> , <i>Thracia</i> , <i>Procerithium</i> and small <i>Lingula</i> ; pyrite trails; interburrowed junction at base	0.35	13.85
Mudstone, greyish green with burrowfill from above containing carbonized plant debris; irregular fracture; generally burrow-mottled; scattered small shell fragments including <i>Oxytoma</i> , <i>Palaeoneilo</i> , <i>Protocardia</i> , oysters and <i>Procerithium</i>	0.55	14.40
Mudstone, as above, but better laminated and with a more regular fracture; <i>Palaeoneilo</i> , <i>Protocardia</i> (in clusters), and bivalve fragments with shell debris; <i>Dicroloma</i> ; <i>Kosmoceras</i> and oysters in 'plaster' at 14.45 m	0.30	14.70
Mudstone, medium grey, even-textured with shell fragments rather rare; easily breaking with smooth fracture along bedding; <i>Protocardia</i> and <i>Kosmoceras</i> fragments including <i>K. (Z.) cf. obductum</i> at 14.79 m	0.15	14.85
Mudstone, greyish green, with less even fracture than above and with rare nacreous shell debris, mainly bivalve fragments; <i>Gryphaea</i> , <i>Palaeoneilo</i>	0.15	15.00
Mudstone, greyish green, smooth fracture surfaces, easily breaking along bedding; shells rather rare but with some small whole bivalves including <i>Entolium</i> , <i>Gryphaea</i> , <i>Meleagrinella</i> , <i>Palaeoneilo</i> , <i>Protocardia</i> and fragments; <i>Kosmoceras</i> fragments including <i>K. (Gulielmites) cf. jason</i> (Reinecke) at 15.02 m; small gastropods	0.30	15.30
Mudstone as above but with more shell debris; <i>Entolium</i> , <i>Grammatodon</i> , <i>Gryphaea</i> ; <i>Oxytoma expansa</i> in plaster at 15.43 m; <i>Dicroloma</i> , serpulid and <i>Kosmoceras sp.</i> at 15.41 m	0.13	15.43
Shell bed with <i>Meleagrinella</i> common, and other bivalve and ammonite fragments	0.07	15.50
Mudstone, medium grey, breaking along bedding with even fracture; shells relatively rare; faint burrow-mottling in places; <i>Palaeoneilo</i> , <i>Posidonia</i> , <i>Thracia</i> , <i>Procerithium</i> ; nucleus of perisphinctid ammonite at 15.55 m	0.40	15.90
Mudstone, medium grey as above but with more shell debris; <i>Dicroloma</i> ; small perisphinctid ammonite at 15.95 m; and large nacreous fragments of <i>Kosmoceras</i> at 16.05 m ..	0.20	16.10
Mudstone, as above but paler and with blocky fracture; <i>Kosmoceras</i> fragments and small <i>Entolium</i>	0.10	16.20
Mudstone, medium grey, shell debris decreasing downwards; fracture even along bedding; bivalve fragments including <i>Pinna?</i> , <i>Protocardia</i> ; <i>Dicroloma</i> , serpulid, <i>Kosmoceras</i> fragments	0.30	16.50

<i>Description of Strata</i>	<i>Thickness m</i>	<i>Depth m</i>
Mudstone, pale grey with even fracture in places tending to blocky; scattered shell fragments including <i>Dicroloma</i> , <i>Procerithium</i> with <i>Kosmoceras</i> and perisphinctid ammonite fragments at 16·65 and 16·88 m	0·38	16·88
Mudstone, medium grey with even fracture; shells increasing with depth; <i>Entolium?</i> , <i>Oxytoma expansa</i> , <i>Gryphaea</i> , <i>Palaeoneilo</i> , <i>Posidonia</i> , <i>Protocardia</i> and other bivalve fragments, <i>Procerithium</i> and <i>Kosmoceras</i> fragments ..	0·32	17·20
Mudstone, medium grey, silty, with small shell fragments and pyrite specks; <i>Grammatodon</i> cf. <i>gnoma</i> (d'Orbigny), <i>Palaeoneilo</i> , <i>Posidonia</i> (in clusters), <i>Protocardia</i> , <i>Dicroloma</i> , <i>Procerithium</i> , <i>Dentalium</i> , <i>Kosmoceras</i> fragments	0·30	17·50

Kosmoceras jason Zone

K. jason Subzone

Mudstone, medium greyish green, brittle, fracturing easily along bedding with smooth fracture surfaces; shells scattered throughout with <i>Corbulomima?</i> , <i>Grammatodon</i> , <i>Meleagrinnella</i> , <i>Palaeoneilo</i> (common in places), <i>Posidonia</i> , <i>Protocardia</i> , <i>Thracia</i> and oysters; <i>Kosmoceras</i> fragments including inner whorls of <i>K. (G.) cf. jason</i> at 18·40 m and a coarsely ribbed <i>K. guillemi</i> (J. Sowerby) at 18·44 m; <i>Grossouvria</i> fragment at 18·10 m; <i>Dicroloma</i> , <i>Procerithium</i> , fish debris and belemnite at 17·67 m	1·20	18·70
Mudstone, medium grey with very uneven fracture; <i>core disturbed</i> from 18·70 to 18·80 m; <i>Kosmoceras</i> fragments with <i>Gryphaea</i> , <i>Protocardia</i> and <i>Procerithium</i>	0·45	19·15
Mudstone, as above, but with less uneven fracture; <i>core less broken</i> ; fracture surface with sooty pyritic debris at 19·48 m; fossils rather rare; <i>Posidonia</i>	0·33	19·48
Mudstone, medium greyish green, smooth textured, with fracture very even; in places brittle and breaking into thin flakes; shell debris sparse; <i>Meleagrinnella</i> preserved in pyrite; <i>Dicroloma</i> , <i>Procerithium</i> , <i>Kosmoceras</i> fragments..	0·32	19·80
Mudstone, pale to medium grey, fracture uneven and crumbly, tending to blocky from 19·90 m; <i>Grammatodon</i> cf. <i>gnoma</i> , <i>Meleagrinnella</i> (preserved sometimes in bright pyrite), <i>Oxytoma expansa</i> , <i>Palaeoneilo</i> , <i>Thracia</i> ; tiny gastropods including <i>Procerithium</i> ; belemnite fragment; <i>Kosmoceras</i> including <i>K. (G.) cf. jason</i> at 20·42 m and <i>K. (Guillemiceras)</i> cf. <i>guillemi</i> at 21·04 and 21·08 m	1·30	21·10
Mudstone, medium grey, texture becoming coarser with depth; fine shell and dark organic matter scattered throughout; <i>Kosmoceras</i> common including <i>K. (G.) jason</i> at 21·27 m, 21·41 m, 21·50 m and 21·69 m; <i>Reineckeia</i> fragment at 21·62 m; fish and bivalve fragments including <i>Posidonia</i> (forming plaster at 21·60 m), <i>Protocardia</i> and a plaster of <i>Pinna</i> at 21·67 m; passing down into	0·71	21·81

Description of Strata	Thickness m	Depth m
K. jason Zone		
K. medea Subzone		
Mudstone, medium grey; shelly and 'earthy' at the top but rapidly becoming even-textured with depth, splitting easily along bedding; <i>Kosmoceras</i> abundant mainly as fragments but including <i>K. (G.) cf. jason</i> at 22·26 and 22·32 m, <i>K. (Gulielmites) medea</i> Callomon at 22·38 and 22·52 m and <i>K. (Gulielmiceras)</i> , <i>Corbulomima</i> , <i>Oxytoma</i> , <i>Pinna</i> , <i>Posidonia</i> , <i>Protocardia</i> , <i>Dicroloma</i> , epizoic oysters on some ammonites	0·74	22·55
Mudstone, medium greyish green, smooth-textured with less shell material than above; splits easily along bedding; <i>Kosmoceras</i> fragments including <i>K. (G.) aff. medea</i> at 22·63 m and <i>K. (G.) cf. jason</i> at 23·01 and 23·05 m; <i>K. (G.) gulielmi</i> common; <i>Choffatia?</i> at 23·05 m; bivalve fragments and debris including <i>Corbulomima</i> , <i>Pinna</i> , <i>Posidonia</i> , <i>Protocardia</i> and oysters; fish debris	0·50	23·05
Mudstone, medium to dark grey, more silty than above; very dark grey in places; carbonized plant debris on bedding surfaces, <i>Kosmoceras</i> including <i>K. (G.) jason</i> at 23·17 m, <i>K. (G.) gulielmi</i> at 23·19 m and pyrite-filled <i>K. (G.) cf. medea</i> body-chamber fragment at 23·23 m; <i>Grossouiria?</i> fragment at 23·17 m; bivalve fragments including <i>Pinna</i> and oysters becoming common; pyritic <i>Gryphaea</i> -rich band at base with ammonite and bivalve fragments, and small gastropods	0·25	23·30
Mudstone, medium to pale grey, rather crumbly to 23·55 m; smoother below with more even fracture; ammonite fragments including <i>Kosmoceras (G.) gulielmi</i> , <i>Gryphaea</i> , <i>Meleagrinnella</i> , <i>Oxytoma expansa</i> , <i>Palaeoneilo?</i> , <i>Thracia</i> and other bivalve fragments, <i>Procerithium</i>	0·50	23·80
Oyster bed with <i>Gryphaea</i> and ammonite fragments	0·05	23·85
Mudstone, medium grey, becoming silty and ?more calcareous with listric surfaces on shelly layers with bivalves, including small oysters, and <i>Kosmoceras</i> fragments; <i>Meleagrinnella</i> , <i>Oxytoma</i> and small gastropods	0·13	23·98
Oyster bed with <i>Astarte</i> , <i>Meleagrinnella</i> and other bivalve fragments; core more crumbly with increased shell content	0·07	24·05
Mudstone, interburrowed light and dark grey becoming silty and carbonaceous in places; <i>Oxytoma</i> , <i>Posidonia</i> , small <i>Protocardia</i> , <i>Thracia</i> and small oysters; <i>Procerithium</i> , <i>Kosmoceras</i> fragments and <i>Pseudocadoceras?</i> at 24·12 m	0·19	24·24
Shell band; silty mudstone with wood and belemnite fragments; bivalves including oysters	0·02	24·26
Mudstone, pale to medium grey, less silty than above with more uniform texture and even fracture; becoming slightly coarser and harder with depth; bivalves including <i>Oxytoma</i> , <i>Palaeonucula</i> , <i>Posidonia</i> , small belemnite, <i>Dicroloma</i> and <i>Kosmoceras</i> , including <i>K. (G.) cf. medea</i> at 24·44 m	0·36	24·62
Oyster bed; silty mudstone, medium grey, coarse-textured, with <i>Gryphaea</i> and <i>Kosmoceras</i>	0·08	24·70

Description of Strata	Thickness m	Depth m
<i>Sigaloceras calloviense</i> Zone		
<i>S. enodatum</i> Subzone		
Mudstone, medium to pale grey, with silty patches, pyrite streaks and shell debris; rather crumbly; becoming slightly less silty with depth; fracture blocky and fossils few; <i>Chlamys</i> , <i>Kosmoceras</i> (<i>Gulielmiceras</i> ?), ? <i>Sigaloceras</i> (<i>Cata-sigaloceras</i>) <i>enodatum</i> (Nikitin) at 25.05 m	0.35	25.05
Oyster bed	0.05	25.10
Mudstone, medium grey, burrow-mottled, texture smoother than above, breaking more easily; becoming paler, more brittle, fracture surfaces smoother and fossils rarer with depth; <i>Myophorella</i> , <i>Palaeonucula</i> , plaster of tiny <i>Posidonia</i> at 25.84 m, <i>Thracia</i> ; <i>Sigaloceras</i> spp. including <i>S. (C.)</i> aff. <i>enodatum</i> at 25.17 m and <i>Kosmoceras</i> (<i>Gulielmiceras</i>); <i>Proplanulites</i> ? fragment at 25.25 m.. .. .	0.74	25.84
Mudstone, as above but poorly fossiliferous, becoming more silty with depth; large <i>Oxytoma expansa</i>	0.17	26.01

KELLAWAYS BEDS

KELLAWAYS ROCK

S. calloviense* ZoneS. calloviense* Subzone

Siltstone, grey becoming coarser in texture to almost sandstone with depth, rather friable, breaking easily with irregular fracture; becoming very fossiliferous downwards; <i>Anisocardia</i> cf. <i>minima</i> (J. Sowerby), <i>Astarte</i> , <i>Chlamys fibrosa</i> , <i>Gryphaea</i> (common), <i>Myophorella</i> , <i>Oxytoma expansa</i> ; <i>Keplerites</i> ? fragment at 26.10 m, <i>Sigaloceras</i> (<i>Gulielmina</i> ?) and <i>Proplanulites</i> fragments at 26.35 m; fragments of small to medium-sized belemnites; interburrowed junction at base	0.49	26.50
Sandstone, greyish green, hard, compacted, calcite-cemented, very shelly with <i>Chlamys fibrosa</i> , <i>Gryphaea</i> (common), <i>Modiolus</i> , <i>Pleuromya</i> and other bivalve fragments; <i>Ornithella</i> ? fragment; pale, smooth burrowfills in top 0.05 m; interburrowed junction at base	0.38	26.88
Siltstone, becoming argillaceous, less well cemented and more friable downwards, with muddy patches; sandy burrowfills in top 0.10 m; <i>Chlamys</i> , <i>Entolium demissum</i> , <i>Modiolus</i> , <i>Pleuromya</i> , small oysters, large terebratulid (<i>Ornithella</i> ?) and smaller rhynchonellid brachiopods; shells becoming sparse with increasing depth.. .. .	0.42	27.30
<i>Core disturbed</i>	0.10	27.40
Siltstone, fine-grained, easily broken, with shell fragments including a gastropod and rhynchonellid brachiopods; in places becoming friable, greyish green sandstone; interburrowed junction at base with silty burrowfills in mudstone	0.30	27.70

Description of Strata	Thickness m	Depth m
Core damaged, partly lost	0.30	28.00
Sandstone, fine-grained, friable becoming more consolidated with depth; fine burrow-mottling showing strong pale/dark colour differentiation, in places burrowfills very muddy; less fossiliferous and less burrow-mottled towards base; <i>Chlamys fibrosa</i> , <i>Entolium demissum</i> , <i>Grammatodon</i> , <i>Meleagrinnella</i> , <i>Myophorella</i> , <i>Nuculana</i> , <i>Oxytoma</i> , <i>Pleuromya alduini</i> , <i>Protocardia</i> , oysters, wood fragments, small belemnite; <i>Proplanulites</i> fragments at 28.49 and 28.60 m; interburrowed junction at base	0.75	28.75

KELLAWAYS CLAY

S. calloviense Zone*Proplanulites koenigi* Subzone

Siltstone, very muddy in places, fewer fossils than above, fracture fairly even along bedding; <i>Camptonectes lens</i> (J. Sowerby), <i>Corbulomima</i> , <i>Grammatodon</i> , <i>Meleagrinnella</i> , <i>Oxytoma</i> , <i>Palaeonucula</i> , <i>Pleuromya alduini</i> and oysters; ammonite fragments including <i>Keplerites</i> s.s. at 29.79 m, <i>Cadoceras?</i> at 30.29 m and <i>Proplanulites?</i> at 29.20 m; interburrowed junction at base	1.60	30.35
Sandstone, grey, calcite-cemented; shell fragments including <i>Camptonectes lens</i> , <i>Meleagrinnella</i> , <i>Modiolus bipartitus</i> J. Sowerby, <i>Myophorella</i> and small oysters	0.25	30.60
Sandstone, greyish green, fine-grained, rather soft and barren; becoming calcite-cemented and harder at 30.75 m but less well cemented in parts below; scattered shell fragments including <i>Anisocardia?</i> , <i>Grammatodon</i> , <i>Meleagrinnella</i> , <i>Myophorella</i> , <i>Oxytoma expansa</i> , <i>Pleuromya</i> , small oysters, serpulids	0.90	31.50
Sandstone, greyish green, harder than above with occasional shells including <i>Gryphaea</i> , <i>Meleagrinnella</i> , <i>Myophorella</i> , <i>Procerithium</i> ; interburrowed junction at base	1.00	32.50
Mudstone, pale grey, sandy in upper part becoming increasingly silty and muddy with depth; fracture more even than above with shells rather rare; <i>Grammatodon</i> , <i>Meleagrinnella</i> , <i>Thracia</i> , <i>Proplanulites</i> at 33.08 m with inner whorls preserved in pyrite; pyrite trails and patches	1.52	34.02
Core damaged, partly lost, but cementstone nodule with calcite-filled septarian cracks in mudstone matrix seen in debris at 34.07 m	0.18	34.20
Mudstone, pale grey with <i>Corbulomima?</i> , <i>Gryphaea</i> , <i>Oxytoma expansa</i> , <i>Protocardia</i> ; interburrowed junction at base	0.20	34.40
Mudstone, pale grey, very silty and sandy in places with nests and trails of pyrite; small <i>Gryphaea</i> , <i>Meleagrinnella</i> , <i>Modiolus</i> , <i>Myophorella</i> , <i>Pleuromya</i> , <i>Protocardia</i> and wood fragments	1.65	36.05
Core lost	0.05	36.10

Description of Strata	Thickness m	Depth m
Siltstone, in parts sandy; some patches of greyish green mottled mudstone; shells including <i>Anisocardia</i> aff. <i>minima</i> , <i>Catinula alimena</i> , <i>Gryphaea</i> , <i>Modiolus</i> , <i>Myophorella</i> , <i>Pleuromya</i> , <i>Protocardia</i> and <i>Thracia</i>	0.55	36.65
Oyster bed	0.05	36.70
Mudstone, silty, greyish green with sandy burrowfills; <i>Astarte</i> , <i>Catinula alimena</i> , <i>Gryphaea</i> , 'Lucina', <i>Myophorella</i> , <i>Oxytoma</i> , <i>Pleuromya alduini</i> , serpulids, <i>Ornithella ornithocephala</i> and rhynchonellid brachiopods	0.40	37.10
Siltstone, soft, bioturbated, greyish green becoming harder and well cemented below 37.30 m; <i>Catinula</i> , <i>Gryphaea</i> , <i>Modiolus bipartitus</i> , <i>Myophorella</i> , <i>Pholadomya</i> , <i>Pleuromya alduini</i> , <i>Protocardia</i> , serpulids; with <i>Proplanulites</i> sp. at 37.15 m and uncrushed <i>Chamousetia</i> fragment with cream-coloured infilling at 37.80 m	0.70	37.80
Core shattered, partly lost; apparently silty mudstone with <i>Cadoceras?</i> at 37.86 m	0.40	38.20
Mudstone, medium grey, less silty than those above, with smooth fracture; few pyrite trails and rare fossils with pyrite relics of bivalves; <i>Protocardia?</i> and <i>Thracia?</i>	0.50	38.70
Mudstone, greyish green, silty, burrow-mottled with <i>Pleuromya alduini</i>	0.28	38.98
Shell bed, very hard, calcite-cemented; <i>Catinula</i> abundant, <i>Myophorella</i> , other oyster fragments common	0.02	39.00
Mudstone, core disturbed, shells common including <i>Catinula</i> , <i>Oxytoma expansa</i> ; crushed pyritic ammonite nucleus at 39.30 m (kosmoceratid?)	0.30	39.30
Siltstone, muddy with sandy patches; shells include <i>Camptonectes</i> , <i>Catinula alimena</i> , <i>Modiolus</i> , <i>Myophorella</i> , <i>Pleuromya</i> and ?rhynchonellid brachiopod fragment at 39.52 m	0.30	39.60
Siltstone, greyish green, soft, calcareous, bioturbated in places, shelly with <i>Anisocardia</i> , <i>Catinula</i> cf. <i>alimena</i> , <i>Corbulomima</i> , <i>Grammatodon</i> , <i>Meleagrinella</i> , <i>Modiolus</i> , <i>Myophorella</i> , <i>Palaeonucula</i> , <i>Pleuromya</i> cf. <i>alduini</i> , <i>Protocardia</i> , serpulids, wood fragments, <i>Procerithium</i> ; creamy (phosphatic?) nodule at 41.54 m and <i>Modiolus bipartitus</i> at 42.20 m with infilling of similar material; interburrowed junction at base	2.60	42.20

Macrocephalites macrocephalus Zone

M. kamptus Subzone

Mudstone, medium grey, brittle with smooth texture and even fracture, in part burrow-mottled with sandy burrowfills, which in places dominate the lithology; pyrite specks in places; <i>Corbulomima</i> , <i>Modiolus</i> cf. <i>bipartitus</i> , small oysters, serpulids and <i>Procerithium</i> ; fragments of <i>Macrocephalites</i> at 42.50, 43.30 and 43.31 m	1.60	43.80
Core disturbed, partly lost	0.40	44.20

<i>Description of Strata</i>	<i>Thickness m</i>	<i>Depth m</i>
Mudstone, as above, but more silty or sandy with bivalve fragments including <i>Corbulomima</i> , <i>Grammatodon</i> , <i>Pleuromya</i> and small oysters; <i>Dicroloma</i> , <i>Procerithium</i> and serpulids	0.38	44.58
GREAT OOLITE SERIES		
CORNBRASH		
Limestone, in part bioturbated and silty, with poorly preserved fauna; <i>Entolium</i> , <i>Goniomya</i> , ' <i>Lucina</i> ', <i>Modiolus</i> , <i>Pleuromya</i> , small oysters, <i>Procerithium</i> and rhynchonellid brachiopod	0.82	45.40
Limestone, dense, grey with calcite veins; reduction in core diameter; fossils rare; softening towards 46.00 m; inter-burrowed base	0.90	46.30
CORNBRASH (continued)	1.09	47.39
FOREST MARBLE	23.06	70.45
GREAT OOLITE	24.70	95.15
FULLER'S EARTH to base of borehole	7.60	102.75

Tytherton No. 3 Borehole

Drilled by Bristol Avon River Authority; November 1970.
National Grid reference ST 9440 7445. AOD 45.47 m.
IGS Specimens Nos. BDB 9174-9643.

This borehole was drilled to a depth of 91.25 m and proved a full Jurassic sequence from the Kellaways Rock to the Fuller's Earth. The lithological log was prepared by Mr R. J. Wyatt.

JURASSIC

<i>Description of Strata</i>	<i>Thickness m</i>	<i>Depth m</i>
<i>Core commences</i> ..		3.35
KELLAWAYS BEDS		
KELLAWAYS ROCK		
<i>Sigaloceras calloviense</i> Zone		
<i>S. calloviense</i> Subzone		
Sandstone, medium to greenish grey, fine-grained, very muddy, soft and weakly indurated with disseminated pyrite below 4.08 m; sand grains subrounded, moderately well sorted; bivalves common including <i>Astarte</i> , <i>Chlamys</i> cf. <i>fibrosa</i> , <i>Gryphaea</i> , <i>Pleuromya</i> ; belemnite and ammonite (<i>Proplanulites</i> ?) fragments at 4.14 m; coffee-coloured nodules with darker kernels (?phosphatic) at 4.19 m; becoming calcareous towards base	0.95	4.30
Sandstone, medium grey, calcareous, very muddy, shelly, with <i>Chlamys</i> , <i>Gryphaea</i> and <i>Pleuromya</i> ; bioturbated with many burrow traces	0.18	4.48

Description of Strata	Thickness m	Depth m
Limestone, medium grey, fine-grained, sandy and muddy with some disseminated pyrite; crystalline calcite cement; scattered shells including <i>Anisocardia</i> , <i>Astarte</i> , <i>Camptonectes</i> , <i>Chlamys</i> , <i>Gryphaea</i> , <i>Mytilus</i> (<i>Pernomytilus</i>)?, <i>Oxytoma</i> , <i>Pleuromya</i> cf. <i>uniformis</i> ; rhynchonellid brachiopods at 4·70 and 4·73 m and several 'Ornithella' at 4·81 and 4·85 m; <i>Pentacrinus</i> columnals at 4·67 m; <i>Proplanulites</i> at 4·58, 4·68, 4·77 and 4·84 m; <i>Kepplerites</i> fragment at 4·70 m; wood fragment at 4·81 m	0·43	4·91
Mudstone, medium grey, blocky, silty with many sandy patches; scattered bivalves including <i>Gryphaea</i> , <i>Oxytoma expansa</i> , <i>Thracia</i> ?; pyrite knots and trails; terebratulid brachiopod at 5·15 m	0·34	5·25
Sandstone, medium grey, fine-grained, muddy, friable; scattered bivalves including <i>Gryphaea</i> , 'Lucina', <i>Myophorella</i> , <i>Thracia</i> ?, large 'Ornithella' at 5·30 m; strongly bioturbated; small ammonite fragment (kosmoceratid?) at 5·73 m	0·69	5·94
Sandstone, medium grey, fine-grained, muddy, calcareous, fairly well-cemented; scattered bivalves including <i>Modiolus bipartitus</i> and oyster fragments; interburrowed junction at base	0·16	6·10
Limestone, pale grey, fine-grained, sandy, massive, shelly with <i>Anisocardia</i> cf. <i>minima</i> , <i>Gryphaea</i> , <i>Modiolus</i> ; small terebratulid brachiopod at 6·14 m	0·28	6·38
Sandstone, medium grey, fine-grained, very muddy, soft, shelly with indeterminate bivalve fragments; many pyritous patches	0·05	6·43
Mudstone, pale grey, slightly sandy, blocky with scattered bivalves with <i>Ceratomya</i> ?, small <i>Gryphaea</i> , <i>Pinna</i> , <i>Pleuromya</i> ; 'Ornithella' at 6·52 m; burrow-mottled with fine chondritic mottling below 6·58 m	0·20	6·63
Sandstone, medium grey, fine-grained, muddy, soft, shelly with <i>Chlamys</i> , <i>Gryphaea</i> , <i>Pleuromya</i> and several 'Ornithella'; bioturbated	0·32	6·95

KELLAWAYS CLAY

S. calloviense Zone*Proplanulites koenigi* Subzone

Mudstone, pale greenish grey, silty, blocky, burrow-mottled with sandy burrowfills; occasional shell fragments including <i>Myophorella</i>	0·23	7·18
Mudstone, pale greenish grey, coarsely silty, poorly bedded with many shell fragments including <i>Chlamys</i> , <i>Entolium</i> , <i>Grammatodon</i> , <i>Gryphaea</i> , <i>Myophorella</i> , <i>Palaeoneilo</i> , <i>Palaeonucula</i> ?, <i>Pleuromya alduini</i> ; crushed inner whorls of <i>Proplanulites</i> at 7·42 m, <i>Kepplerites</i> and belemnite fragment at 7·54 m	0·60	7·78
Mudstone, pale to greenish grey, very silty, blocky; scattered bivalves including <i>Gryphaea</i> ; pyrite knots and trails; ?fish debris at 7·85 m	0·72	8·50

Description of Strata	Thickness m	Depth m
Limestone, pale brownish grey, fine-grained, muddy and silty with irregular fracture	0.17	8.67
Mudstone, pale to medium grey, poorly bedded, very silty with scattered bivalves including <i>Anisocardia</i> , <i>Astarte</i> , <i>Camptonectes</i> , <i>Catinula alimena</i> , <i>Chlamys</i> , <i>Corbulomima</i> , <i>Entolium?</i> , <i>Grammatodon</i> , <i>Gryphaea</i> , <i>Modiolus</i> , <i>Myophorella</i> , <i>Pleuromya</i> , <i>Pseudolimea?</i> , <i>Thracia</i> ; fragments of <i>Kepplerites</i> s.s. at 9.21 m; rare serpulids at 11.90 m and wood fragment at 8.70 m; becoming very sandy with depth, in places forming a weak muddy sandstone ..	3.61	12.28
Mudstone, pale greenish grey, silty and very silty; scattered pyrite knots and trails; wood fragments at 12.53 and 12.80 m; scattered shells including <i>Grammatodon</i> , <i>Gryphaea</i> , ' <i>Lucina</i> ', <i>Pleuromya</i> , <i>Thracia</i>	1.12	13.40
Mudstone, pale to greenish grey, slightly silty, scattered pyrite knots and trails; cementstone nodule at 13.65 m; sandy lenses and burrowfills in places; <i>Meleagrinnella</i> , <i>Myophorella</i> , <i>Thracia</i>	1.66	15.06
Mudstone, medium grey, very sandy, weakly calcareous, bioturbated with some muddy trails; scattered shells with <i>Grammatodon</i> , <i>Gryphaea</i> , <i>Myophorella</i>	0.40	15.46
Mudstone, medium brownish grey, blocky, very sandy with scattered bivalves including <i>Entolium</i> cf. <i>demissum</i> , <i>Grammatodon</i> , <i>Gryphaea</i> , <i>Modiolus</i> , <i>Myophorella</i> , <i>Oxytoma expansa</i> , <i>Pleuromya</i> ; rare serpulids and <i>Procerithium</i> ..	1.32	16.78
Mudstone, pale greenish grey, silty, shelly with <i>Astarte</i> , <i>Chlamys</i> , <i>Entolium</i> , <i>Grammatodon</i> , <i>Gryphaea</i> , <i>Myophorella</i> , <i>Pleuromya alduini</i> , <i>Thracia?</i> ; terebratulid brachiopod at 17.33 m; scattered pyrite patches and staining; ?erosional parting at base	0.76	17.54
Mudstone, medium brownish grey, blocky, coarsely silty, locally burrow-mottled; <i>Camptonectes</i> , <i>Meleagrinnella</i> , <i>Modiolus</i> and many oysters	0.21	17.75
Mudstone, pale grey, silty to very silty with scattered bivalves including <i>Protocardia</i> and oysters; <i>Proplanulites?</i> at 18.50 m; pyrite knots and trails; creamy ?phosphatic nodule at 17.98 m; becoming less silty and more fissile below	1.18	18.93
Mudstone, medium grey, blocky, silty to sandy with scattered bivalves including <i>Anisocardia</i> , <i>Catinula alimena</i> , <i>Corbulomima</i> , <i>Entolium</i> , <i>Gryphaea</i> , <i>Meleagrinnella</i> , <i>Modiolus bipartitus</i> , <i>Oxytoma expansa</i> , <i>O. inaequalis</i> , <i>Palaeonucula?</i> , <i>Pinna</i> , <i>Placunopsis?</i> , <i>Pleuromya alduini</i> , <i>Protocardia</i> , <i>Thracia</i> , <i>Procerithium</i> , scattered serpulids and wood fragments; ' <i>Ornithella</i> ' at 19.90 m; inner whorls of <i>Macrocephalites?</i> at 21.16 m, <i>Sigaloceras?</i> at 21.44 m and <i>Cadoceras?</i> at 21.77 m; many pyrite patches and shell infillings	3.47	22.40

<i>Description of Strata</i>	<i>Thickness m</i>	<i>Depth m</i>
<i>Macrocephalites macrocephalus</i> Zone		
<i>M. kamptus</i> Subzone		
Mudstone, medium grey, silty, scattered bivalves including <i>Anisocardia?</i> , <i>Corbulomima</i> , <i>Modiolus bipartitus</i> , <i>Nuculana?</i> , <i>Palaeoneilo</i> , with serpulids and <i>Procerithium</i> ; <i>Keplerites?</i> fragment at 23·88 m; pyrite patches and infillings; becoming fissile below with some coarse silty partings; distinct junction at base	1·87	24·27
GREAT OOLITE SERIES		
CORNBRASH		
Marl, medium grey, very sandy and coarsely silty, blocky, very calcareous; very shelly in top 0·02 m with <i>Goniomya</i> and other myids; many small pyritous patches; becoming hard below 24·60 m	0·53	24·80
Limestone, medium grey, fine-grained, argillaceous, silty, hard, massive with scattered bivalves and sporadic rhynchonellid brachiopods; becoming pale grey, very hard limestone below 25·20 m with some fine shell debris	0·53	25·33
CORNBRASH (continued)	3·33	28·66
FOREST MARBLE	22·14	50·80
GREAT OOLITE	23·62	74·42
FULLER'S EARTH to base of borehole	16·83	91·25